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Experimental Study
IN
Thoracic Surgery

BY
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LOS ANGELES, CAL.



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EXPERIMENTAL STUDY IN THORACIC SURGERY.¹

REPORT OF COMMITTEE ON SURGERY.

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The general acceptance by medical and scientific men, the world over, of the germ theory of disease, has, during the past decade, greatly stimulated investigation and research. In no branch of science has this stimulation borne more useful fruits than in bacteriology. To this new science (whose very name but a few years ago was yet unclaimed) are due the marvellous advances which have well-nigh revolutionized this branch of the healing art.

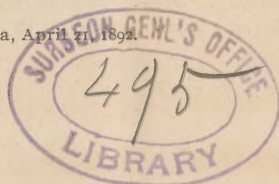
It may be said that the surgeon of to-day, forgetting the prejudices and limitations of his art, is no respecter of tissues. He has fearlessly attacked the great cavities of the body and, thanks to a thorough appreciation of the importance of asepsis and antisepsis, has been enabled to relieve untold suffering, and made life possible, where, under the old dispensation, there was naught but hopelessness and death.

The peritoneal and cranial cavities having been successfully invaded for the relief of morbid conditions, and their invasion having become an established surgical procedure, the thoracic cavity next claimed the attention of the progressive surgeon.

While the operation of thoracentesis is as old as Hippocrates, it having been, in fact, first advocated and described by the great philosopher himself for the relief of pulmonary abscess and empyema, the operation of thoracoplasty—pneumonotomy as it is now understood—and pneumonectomy are essentially modern.

The first of these, originally proposed by the French clinician, Letievant, for the relief of empyema, was subsequently performed and described by the Swedish surgeon, Estlander. The operation of pneumonotomy, undertaken for the relief of abscesses situated within the lung tissue—gangrene—the drainage of echinococcus cysts and tubercular cavities, has become an established surgical procedure, and, under a more strict antisepsis than was formerly obtained, has of late been attended with good results.

¹ Read before the Medical Society of the State of California, April 27, 1892.



If we except a few isolated cases, recorded throughout medical literature, in which a herniated portion of lung tissue—the result of traumatism—was excised, and the removal of rare superficial tumors of the lung, pneumonectomy is, on the other hand, an essentially new operation.

It is not the purpose of the writer to dwell upon the history of the first two operations mentioned, nor to present a statistical study of the results obtained up to the present time; such details may be found in the various surgical text-books and journal articles of recent years. The selection of a subject for discussion before this section at the present meeting was a matter of some difficulty. Having watched with great and increasing interest the labors of others in this and foreign countries, the writer decided to investigate the promising field of pneumonectomy for himself, and the present paper is the result of this decision. He has hoped to add his mite of information to the knowledge of this important subject, which he believes and predicts will, within the next ten years, become one of general interest to the profession.

From being, at the present time, a curiosity of the laboratory, pneumonectomy will soon take rank with the other operations devised for the relief of morbid conditions within the abdominal and cranial cavities. Before it becomes so, however, much laborious research and experimentation will be necessary. Notwithstanding the hysterical outcries of the "anti-vivisectionists" in this and other countries, particularly in England, the lower animals must continue to be sacrificed in our laboratories for the eventual benefit of mankind. With the improved methods of producing insensibility in the animals selected for experimentation, it is now possible to carry out this work with the minimum amount of suffering.

The writer struggled for a time against a very natural aversion to inflict suffering upon dumb animals. This feeling was at last overcome, and the work undertaken with the firm conviction that our knowledge of surgical possibilities in man can be best studied by careful experiments upon animals. Any unprejudiced reader, who has intelligently followed the labors of Ferrier and Horsley in the difficult field of brain localization, cannot fail to reach the same conclusion.

The *impossible* of yesterday is the *accepted* and *successful procedure* of to-day, and surgical operations are daily performed which were undreamed of half a century ago. Had these been attempted at that time, and attended with unfavorable results, the surgeon would have been censured, prosecuted for murder, perhaps; or, on the other hand, if successful, a miracle would have been invoked in explanation. I have but to refer to the early struggles of Ephraim McDowell, the "father of ovariectomy," not to speak of other innovators in surgery.

I had originally intended to experiment on various domestic animals, but finally decided to make use of rabbits only. These were selected because more easily obtained and more manageable in the laboratory. Also their well-known low vitality, naturally diminishing the chances of their recovery from a given operation, would in the event of recovery render the test even more conclusive. Lastly, these experiments, for the sake of convenience and economy of time, having been conducted in the writer's own residence (the animals being confined

in basement under porch) the unpleasant odors from such a number of animals kept in a pen for weeks were reduced to a minimum by the selection of rabbits. No originality in their selection is claimed by me, these animals having been used in the experiments of other investigators, notably those of the Russian observer Zakharevitch.¹

"Out of thirteen operations performed on nine rabbits by this experimenter, but two resulted fatally, which is justly considered very encouraging."

Zakharevitch also operated eleven times upon dogs, and nine times on the human cadaver. "Having made a subperiosteal resection of from 1 to 4 ribs, he drew a portion of lung out of wound, tied its roots with silk, cut it away, applied iodoform, returned stump, stitched up wound and used a Listerian dressing."

A committee of the Stillé Medical Society of the Undergraduates in Medicine, University of Pennsylvania, composed of Messrs. Bolgiano, Patek and Sailer, have published brief notes of similar experiments upon the lungs of dogs.²

"The general plan of operation first adopted was to resect one or more ribs, draw out and ligate a lobe of the lung, cut off a portion and return the lung into cavity. A catgut drain was then introduced into the thoracic cavity, and the pleura, intercostal muscles and skin were sutured. In the first series of four animals experimented upon, one died on the table, two on the second day after the operation, and one not until the fifth day. Autopsies showed gangrene of the stump and empyema."

These results being so obviously due to the improper methods used, a different operative technique was adopted.

"The site of operation, previously selected in accordance with results obtained on the cadaver under forced respirations, was shaved and carefully disinfected. An incision about two inches long was made down to the intercostal muscles, and the tissues were dissected back a short distance on each side. A quick cut, about one and a half inches long, was then made through the intercostal muscles and pleura. Retractors were immediately inserted and the ribs were drawn apart by an assistant, while the operator thrust in a pair of hemostatic forceps in the direction previously determined, seized the lobe of the lung, drew it out and transfixed it with a sharp probe. As soon as this was accomplished the retractors were withdrawn, allowing the ribs to close upon the lung tissues, the probe preventing retraction during inspiration. The external portion of the lung was now removed by a 'V' incision. A needle, threaded with antiseptic gut, was passed through the intercostal muscle, pleura and tissue of the lung, beneath the incision and out through the pleura and intercostal muscle of the other side. These sutures were repeated about one-eighth of an inch apart until the wound in the thorax was closed, the wound in the lung being closed at the same time. A catgut drain was now laid over the wound and the edges of the skin were brought together." Owing to the difficulty experienced in controlling the dog, it was found necessary to dress the wound with a solution of collodion and iodoform in ether upon a matrix of cotton.

¹ Annual of the Universal Medical Sciences, Sajous, 1890; Vol. III, p. 26.

² UNIVERSITY MEDICAL MAGAZINE, May, 1891, p. 473.

"By this method three dogs were operated upon with most satisfactory results. During the operation shock was not experienced, and but little hemorrhage occurred. In each case the dogs reacted well. Respirations were at first somewhat rapid, and there was an insignificant rise of temperature during the twenty-four hours following the operation. The appetite was good throughout."

Let me here quote the concluding remarks of the article under consideration:

"We think that we may fairly consider these results as indicating a thoroughly satisfactory method of excising portions of the lung from dogs. Whether it is equally applicable to human beings, experience alone can demonstrate. Reasoning *a priori*, it would seem that this technique might be adopted in surgery, for none of the steps depend upon any anatomical peculiarity of the subject. What result it promises, it is, of course, impossible to say; but the beneficial results of operative interference in tubercular peritonitis strongly indicate that much good may come from surgical interference, even when such important viscera as the lungs are involved."

If I may lay claim to any originality in performance of the experiments, it is in my attempt to determine, by repeated operations on the same animal, the limits of surgical interference.

Dr. DeForest Willard, of Philadelphia, in a paper read before the College of Physicians, of Philadelphia, November 4, 1891,¹ reports at length a series of experiments in pneumonotomy and pneumonectomy on dogs, and concludes: "My experiments, though few in number, prove at least that adhesive inflammation can be induced between two pleural surfaces by subcutaneous suturing, and that a route of entrance can thus be readily secured; also that the lung may be incised or a portion of it be removed, without serious injury to the animal. The value of these experiments, in a surgical view, is as yet largely undetermined."

E. Forgue and P. Reclus, in a review of the present status of lung surgery, state as their opinion, that while pneumonectomy may be done on rabbits, it, with the exception of that performed for the removal of superficial tumors of the lungs, is unwarrantable on man.² Their assertion is evidently based upon the results published by Block, Kroenlein and Ruggs. I greatly regret that I have been unable to consult the original articles of these observers, nor to have found any other than this brief mention of their work.

In the experiments about to be described I have profited by the work of my former Professor at the University of Pennsylvania, Dr. Willard, and have followed the methods used by him in his operations upon dogs. The difficulty spoken of by Dr. Willard, of retaining bandages on dogs, and of controlling their movements, is more than offset, I think, by the greater strength of the lung tissue of dogs, in ligation and suture, when contrasted with the extreme delicacy and friability of the lung in rabbits. There is also a very large element of timidity and fright present at every handling of rabbits, even in dressing them, which has entered largely into the otherwise unaccountable deaths of a number of my subjects, where there was not enough pathological change seen to account for sudden death. Here *shock* must cut a large figure, as does heart failure, at the present time, in man.

¹ UNIVERSITY MEDICAL MAGAZINE, Philadelphia, February, 1892, p. 338.

² Gazette de Hebdomadaire de Medicine et de Chirurgie, September, 1891.

The object of these experiments was to learn the following facts:

(1) *The Ease or Difficulty with which various Operations may be carried out upon the Chest and Lungs of Rabbits.*

A condensed schedule of operations performed is as follows: Whole number of operations performed 27, on 20 rabbits; begun January 31st, concluded April 16, 1892.

10 Pneumonectomies.

3 Thoracotomies.

4 Attempted pneumonectomies, with laceration of lung, chest packed with gauze, etc.

8 Sutures of lung: 3 primary operations; 5 secondary.

1 Pneumonotomy.

1 Death from anesthesia. This subject will be referred to later.

(2) *What Part or Parts, and how much Lung can be Safely Removed?* After twenty-seven operations on twenty rabbits, I find that the lower lobes are so much larger and more important, proportionally, than upper and middle lobes, and so much more easy of access, that excision or damage to them is a better test of lung capacity after mutilation than if operation on the upper lobe was not done at all. Several times I have included the middle in pneumonectomies.

In rabbits, owing to the large size of the scapular, pectoralis major and minor muscles, the approach to the upper spaces is very difficult—especially as a wound through different layers is only to be made when the leg is drawn into an unusual position, and when the rabbit is walking about; the wound, through tissues and muscles, loosely attached to one another, is tortuous, and is likely to retain the products of wound healing.

The lungs of an adult rabbit, weighing five or six pounds, weigh from two and a half to three drachms—the right being considerably the larger, the middle being added to the upper and lower lobes, which are about the same size on each side. The heart is almost in the middle, slightly more to the left than right. There is a great similarity between the rabbit and man, in arrangements of parts—far more than one would believe, until parts are dissected. This is strikingly seen in the anatomical arrangement of lungs, diaphragm, ribs, etc.

The easiest place of operation is, for upper or middle lobes, close to sternum, in second or third space, or in case of lower lobe, third or fourth intercostal space, in front, or from behind, beneath and behind scapula, in sixth or seventh space. Pneumonectomies can be done almost any where, but most easily opposite root of lung, from second to fourth space, as there is the least respiratory traction.

The chief difficulty in operating is the exceeding delicacy and friability of the lung tissue, and the maintenance of the proper degree of anesthesia, not enough ether causing struggles as nerves are touched, too much ether either being fatal or necessitating resuscitation. A third difficulty is the impossibility of keeping animal and parts operated upon in a state of quiet, I believe long delayed union and healing of wounds is due largely to muscular friction in operative wounds

In one of my last operations (on No. 18) a plaster-of-Paris bandage was applied at second dressing, to see if by it the movements could be limited and healing thereby hastened. After three days it was decreased in size, and afterward used as a cast, with some benefit, I believe.

The vitality and resistance rabbits show when experimented upon in different ways is certainly wonderful—much greater than would naturally be expected of animals who often die of fright when hunted by dogs or are killed by one shot.

The pleura, I hope to show, is as long-suffering as the peritoneum. In the cases (Nos. 11-16 and 18) where from laceration it was learned by sad experience to be unsafe to allow the bleeding to go on in the thorax, gauze was quickly and firmly packed into chest and allowed to remain several days, and then gradually withdrawn. (In case No. 11 gauze was withdrawn gradually; the animal recovered. No. 18, gauze was left; recovery. No. 16, died in four days, pressure being removed too suddenly.)

The rabbit can live with one lung or its equivalent, if it is uninjured—as has been proved by others in dogs—and can live apparently well with lower lobe removed on one side, and lower on other rendered almost of as little account, by suturing to chest wall.

This subject of how little lung a rabbit can thrive with, would have been pushed further, except for fear of losing some of the best cases by going too far. The time became too short, and it was desirable to have animals operated on live as long as possible. There is no question in my mind but that the pleura is much less inflammable than is usually supposed, at least in rabbits.

All cases where wounds have been made in thorax or lung, under as strict antiseptic precautions as possible, with rabbits, have shown no spread of inflammation outside limits of adhesions, except in Case 8, where pericarditis was set up from lung and rabbit died on eighth day, immediately after second dressing. This is one case against nineteen others. After two or three weeks a wound of the pleura will be obliterated and hard to find. So also in case of the muscles, except intercostals, where space is depressed, but skin retains scar longest of all—first to close and last to lose trace of wound.

(3) *The effects of Operation on Same Animal and on Different Species Contrasted with each other.*—According to these experiments the rabbit bears one operation about as well as another, and, with proper care as to surgical cleanliness, seems not to suffer constitutionally from loss of even largest amounts of lung tissue, or of its usefulness through suture to thoracic wall. This is evidenced by the uninterrupted breeding and completion of pregnancies already begun, operations having been done in all stages of pregnancy, without regard to that condition, and more females have been used for experiment than males. A dozen litters have been born in the rabbit pen, and only two of eight young, in all that have grown up, either were not nursed or were killed by male rabbits. A singular fact learned is, that unless the female immediately after delivery takes the buck, she will not suckle her young, and they invariably die in three or four days.

Having dissected dogs, but not having operated on their lungs, I think the greater strength of their lung tissue is a great factor in success of operations on

dog lungs; and as good results from the same operations as described and performed by Dr Willard in dogs, are, in the rabbit, a more delicate test of the operation, considering the differences of size, strength of tissues and widths of intercostal spaces—the conformation of their chests and muscular arrangements being in main the same and the manner of approach to lung identical.

(4) *Resistance to Sepsis.*—In the first operations the wounds were allowed to go too long without dressing, and discharges retained, but nevertheless throughout the whole series, no matter what the physical condition was, there was never any visible constitutional evidence of sepsis.

No attempt was made to take their temperatures, as rabbits are so timid that handling them so excited them that a temperature under such circumstances would have been unreliable and useless. They ate and ran about when well, or were very quiet when not so. The only way to learn their real condition was to watch them from a distance before going into the pen. Thus could respiration be noticed, increased or diminished above or below normal. Their respiration at all times is more rapid than in man.

It will perhaps be urged that animals show more vitality under operation than man. Can this be proved? If so in what way, unless by the same operation, under the best conditions for each species?

I do not wish to be understood to claim that whatever can be done experimentally on animals, dogs and rabbits, etc., is justifiable in man; but by these experiments, pushed to the vital limit, to endeavor to add something to our knowledge of thoracic surgery—a field in which much can and will be done in the near future.

Operative Methods Employed.—The greatest care was taken and most approved methods used to render all operations as nearly aseptic as possible, it being really comparative only in case of animals with fur on skin, and living altogether in a pen.

At first fur was clipped, washed with bichloride solution 1-1000 and shaved, washed again and wound sponged and irrigated with bichloride solution 1-2000. But the skin of rabbits is so delicate that shaving was given up and fur closely clipped and disinfected. We could see no difference in results after shaving was stopped. All instruments were boiled, hands of operator and assistants carefully disinfected, dressings of sterilized gauze and absorbent cotton, and in every detail as much pains taken as if operating on a human subject.

Sponges were kept in bichloride solution. Iodoform was freely used to dust and fill wounds, and no ill effects noted. A saturated solution of iodoform in collodion was used to cover external wound, pedicle of lung or sutures, and seal suture holes in skin where no external dressings were used.

Wounds were sutured in various ways with interrupted, continuous stitches, in mass, or tissues, layer by layer; where tissues were carefully approximated and no spaces left, the wounds healed most rapidly and satisfactorily. The skin was not allowed to close until deep wounds had closed.

The same operations were dressed differently in every possible way—to see results—with bandages, without bandages. Lung sutured through deep muscles

at bottom of wound, through skin and superficial muscles, suture covered by outer wound, suture through skin, fur clipped and not clipped at all, and no difference as to general results was noticed while especial care was given to this fact.

In Nos. 5 and 13 the same operation in each right pneumonectomy was performed, and as secondary operation left lung sutured to wall on same day and killed and examined same day. Pus was found in and about suture track in one case (5) and not in (13) the other. Condition of rabbits equally good. Hagedorn curved needles of various sizes always used, catgut and silk (carbolyzed) used as suture materials. Catgut always for lung suture.

At all dressings, wounds were dressed dry if possible, edges cleansed, bichloride solution 1-2000, discharges were removed, deep wounds wiped out with bichloride solution and peroxide of hydrogen. Bandages were always drawn firmly, compresses of gauze being retained without difficulty.

Stimulants.—Whiskey and water, and aromatic spirits of ammonia were given to assist reaction.

In one case, No. 18, I used a plaster-of-Paris bandage, to see if immobilization, even partial, would hasten healing and lessen amount of cheesy pus. I believe it did some good, as the result was unusually good. Case will be referred to at length later.

I here ask your patience to allow me to read you notes of two pneumonectomies—two attempted pneumonectomies with laceration of lung and chest packed with gauze—one where gauze was left, as a foreign body, and one where it was gradually removed, and two cases of lung suture. I will be as brief as I can and will show you these specimens and others after this paper is finished.

CASE I.—*Pneumonectomy of Right Lower Lobe.* No. 5 (of whole series). White female, 5 lbs. Operated on February 4, 1892; killed April 15. Hair clipped and shaved; etherized slowly. Incision over seventh space, right side. Little bleeding and retraction of different layers of muscles. Pleura opened in seventh space; lung seized with ring forceps and gently drawn through chest wall and sutured in opening to intercostal muscles—five deep sutures in all. Ligated lung, sutured deep, and superficial muscles separately, and left pedicle of lung outside. Applied iodoform collodion to it; skin drawn closely about pedicle, and iodoform collodion again applied; ether stopped, one drachm having been given—less than usual. Dressing: Sterilized gauze, cotton and gauze binder applied. Rabbit removed to pen. Reaction rapid; animal soon lively; respiration excellent; no râles, heart-beats rapid, but no evidence of failure. Operation finished and dressings applied in forty minutes. Less difficulty than in former operations, as animal was better under ether, and less traction by respiration in lung when caught and sutured.

Feb. 10. Six days after operation. External wound healed; no pus; washed with bichloride solution 1-2000; bandage not touched again for eleven days.

Feb. 21. Removed skin sutures and found considerable cheesy matter, evidently from stump of lung; cleansed with peroxide of hydrogen. Packed cavity with gauze; went too long before second dressing.

Feb. 24. Redressed; less amount of cheesy material; wound curreted, peroxide applied; wiped out dry; dry dressing; no gauze in wound.

March 6. Almost healed; small lump of hard cheesy matter at skin opening; iodoform applied; no gauze; sealed with iodoform collodion.

March 10. Wound scabbed over, needing no attention. Perfectly well. She had a litter of rabbits during healing. This made no difference in healing of wound.

Autopsy, April 15. Rabbit killed seventy-one days after operation (longest time of all). Wound in right side, seen only in skin and deep muscles; seventh space midway between sternum and spine; seventh space depressed; large portion of upper and back part of lower lobe removed; root of upper and middle lobes adherent to fifth and sixth spaces; lower lobe below wound attached by firm adhesions to eighth and ninth spaces. Some adhesion to diaphragm; otherwise pleura not involved, except as stated about wound. Upper and middle lobes somewhat dark in color, lower lobe healthy and inflated.

This rabbit was one of the most vigorous, and made an uninterrupted recovery. Healing retarded only by allowing too long time to elapse between dressings, and the retention of discharges.

CASE II.—*Right Pneumonectomy. Recovery, Sixty Days. With Secondary Lung Suture, Fourteen Days.* No. 13. White female, 6½ lbs.; very wild and strong. Clipped, scrubbed and etherized; operated on February 18. Incision right side, seventh space, below and behind scapula when drawn forward; pleura opened, upper part of lower lobe caught and drawn out of wound, sutured in intercostal space; considerable bleeding; closed intercostal wound with four catgut sutures, through lung and muscles; one around two ribs to maintain pressure on pedicle. Deep and superficial muscles, and skin sutured separately and drawn snugly about pedicle. Iodoform collodion was applied to pedicle. Sterilized gauze and cotton dressing; bandage; time, thirty minutes. Reaction good; no stimulant; stood ether well. At 5 P. M. running about and eating.

From Feb. 19 to 25, doing well; 25, dressed first time. Outer wound healed; sealed with scab. Opened wound; some cheesy material between muscles. Cut and removed catgut sutures, which were found soft and all but one unchanged. Cleansed with peroxide of hydrogen and dusted with iodoform, and packed loosely with gauze, to prevent skin healing too soon for deep wound. Except cheesy material, the wound was healthy and granulations were a beautiful color. Stitch, compress and bandage were employed.

Nos. 5 and 13 disprove the generally accepted fact that white color is an indication of delicacy.

March 5. Neglected too long; overlooked; wound through muscular layers filled with cheesy matter; curreted, wiped out with bichloride gauze, and iodoform applied. Outer wound was kept open with gauze.

March 10. Removed gauze; wound very shallow; no gauze put in wound; bandage; excellent condition.

March 12. Gave birth to litter of four rabbits, while I was in the pen, and so cut bandage off her, and sealed wound with collodion.

March 13. Young all killed by males in pen.

March 20. Wound was perfectly healed.

Autopsy, April 15, fifty-seven days after pneumonectomy. Weight 6½ lbs. Lungs fully inflated and normal; right side thoracic wall removed to show lung; pleura normal. Lower lobe attached firmly to seventh and eighth spaces to edges of intercostal wound. No other adhesions. Upper half of lobe removed. Except scar in skin no evidence of operation was found until rib-muscles were reached; seventh space depressed.

CASE III.—*Laceration of Lung; Chest Packed with Gauze. Recovery.*

No. 11. Operation on February 16: Brown and white female; 6 pounds. Clipped, disinfected and etherized. Incision, left side, fourth space. Sudden collapse due to too much ether. Revived by aromatic spirits of ammonia. Great difficulty in keeping under ether, and when lower lobe was caught and drawn through intercostal incision animal struggled, and lung began to pinch off. Caught with second forceps, but because of pressure and struggles of rabbit, lung was torn and dropped back into chest cavity. A strip of sterilized gauze was hastily packed into the pleural cavity, firmly into apex, less firmly downward, so as not to press on heart. Sutured intercostals and skin muscles hastily, and allowed gauze to protrude through closed wound; stitched up skin. Some puffing before suturing was completed. Iodoform collodion applied, and rabbit quickly placed in pen. One hour after had reacted well; some râles over left chest. Three hours after operation external antiseptic gauze and cotton dressing applied. No chest sounds were heard. Rabbit became lively.

February 16. Moved about, bandage stained with serum; râles and emphysematous sounds, but no other evidence of discomfort.

February 21. Removed dressing and sutures; some cheesy material found among muscular layers; gauze tightly adherent to deep muscles, and lips of intercostal wound; gauze strip only partially removed from within thorax, for fear of setting up hemorrhage. Fresh gauze packed in behind first to give pressure.

February 24. Gauze packed in wound at last dressing removed, and cheesy material covering wound in deep muscles scraped off and thoroughly cleansed; dusted with iodoform; gauze in pleural cavity withdrawn a little more, but one of intercostal sutures passed through gauze strip, which prevents as rapid removal as otherwise. Fresh gauze packed in about old gauze plug; wound was in excellent condition, except cheesy material, which evidently came from the pleura.

February 28. Removed twelve inch strand of gauze. Cut stitch in intercostal wound. No pus; dusted with iodoform; packed wound with dry gauze for pressure.

March 1. Withdrew fifteen inch strand of gauze, thick as a pencil, tore out another suture holding gauze; found serum in chest cavity. Wiped out with bichloride gauze, and loosely packed entire wound; compress and bandage.

March 5. Dressing and packing removed; wound curetted and cleansed; iodoform; very loosely packed to prevent skin healing; bandage.

March 10. Removed dressing; curetted; no packing; wound looking very well; compress and bandage; rabbit in excellent condition.

March 13. Wound very shallow; thoroughly dressed; iodoform. No bandage.

March 20. Entirely healed.

March 20 to April 13. No attention was needed; doing well.

April 13. Killed by pithing.

Autopsy. Fifty-seven days after operation: no loss of weight; not pregnant. Sixth and seventh left ribs cut through to show lower chest, and second, third and fourth taken out above, to show pleura and lung beneath. Adhesion of the two pleural surfaces, with some effusion; lungs inflated fully by a blowpipe; found normal. On cutting healed wound in fourth space, a strand of gauze found and partially withdrawn. All but this small amount of gauze removed before wound finally healed.

The following case, No. 18, is in contrast, the gauze packed in chest not having been removed at all.

CASE IV.—*Resection of Third and Fourth Ribs. Attempted Ligation of Lung in the Chest. Laceration, and Chest Packed with Gauze, which was not Removed. Recovery.*

March 20. Brown and white spotted female; six pounds. Incision in left side, behind forward stretched leg; ligated ribs for vessels; cut between; no bone removed. Caught lung with right-angle forceps, and tried to ligate the withdrawn lung, but it tore off (upper part of lower lobe) and dropped back; chest quickly packed with two strips of bichloride gauze, ends projecting, and placed a pad of gauze over ribs, completely filling wound. Thick gauze compress over all; lamb's-wool and bandage. Very weak, but revived by whiskey and water. Two hours later doing well.

March 23. Removed bandage; wound in good condition. No cheesy matter. Found gauze in the pleural cavity moist, cut off projecting ends at the intercostal space, and left packing within chest.

Deep and superficial wound dusted with iodoform; bichloride gauze compress over wound; wool and cotton well up under leg; plaster-of-Paris bandage applied, hoping to prevent friction of muscles on each other, to hasten healing; (first time used). Have thought perhaps movements of wounded parts on each other provoked cheesy matter. Very difficult to get bandage stiff enough and far enough up under foreleg to prevent movement without cruelty to animal.

March 27. Cut off plaster-of-Paris bandage: too large to-day, so cut out a piece. It had done some good by limitation of movement. Not so much cheesy matter over wound. Seems to be a fatty degeneration of connective tissue; iodoform; no gauze. Reapplied cast, with firm compress beneath. Gauze was seen in deep wound, but no attempt to remove it; left it as a foreign body in chest to determine results.

March 31. Removed plaster cast; wound closed on compress. Large amount of cheesy matter retained. It welled up from deep wound; cleansed, iodoform; firm compress, and cast reapplied. General condition excellent.

April 5. Found pus in wound; washed out with syringe. Bichloride, 1-2500 solution, and curetted wound. Pleural cavity apparently closed. Muscular wound long and tortuous, and friction not entirely stopped by cast. Enough gauze packed in wound to keep skin apart. Plaster-cast not reapplied; compress and bandage.

April 12. Killed by pithing.

Autopsy. Twenty-three days after operation. Viscera normal; wound in skin and muscles opened; considerable cheesy matter in tract of wound, which had appearance of a sinus. Intercostal wound closed by gauze, and cemented by a cheesy material. Left pleural cavity so tightly packed with gauze that it encroached on the other side behind the heart. The gauze firmly adherent to parietal pleura and agglutinated together, forming a solid mass, not to be removed from pleural cavity without considerable force; diaphragm attached to gauze, and held high on left side. Right lung fully inflated from trachea, and perfectly healthy. Ribs cut off on both sides, to allow thorough examination of the pleural cavities. Upper left lung above second rib collapsed, and of no use; respiration entirely with right lung. This is a very unique specimen, and is presented for examination.

CASE V.—*Lung Suture. Secondary Operation No. 5.* No. 5 second operation, April 1. Left side; two sutures through skin and all; lower suture in tenth and out ninth space, from angle of rib toward sternum; inserted deeply to catch diaphragm as well as lung. Upper suture in eighth and out sixth toward sternum through lower lobe; both drawn firmly and tied on skin. Iodoform collodion applied to seal sutures and stitch-holes. Condition as good as before operation; respiration good.

Killed April 15. *Autopsy*, fourteen days after operation. Abdominal viscera normal; found cheesy pus within and without the thorax, in the course of catgut sutures, and in left lobe of liver, into which lower suture passes. Lower lobe of lung, diaphragm and liver adherent to chest wall, from sixth to tenth rib; upper lobe and upper back part of lower lobe normal and inflated. Condition of rabbit not changed. No evidence of sepsis. Altogether not more than one lung with which to breathe. This was one of my best cases.

CASE VI.—*Lung Suture. Secondary Operation*, April 1. No. 13. Left side, three sutures; put in deeply to catch diaphragm if possible, one in eighth out sixth space, second in eighth and out seventh space, third in seventh and out sixth; sealed suture and stitch holes with iodoform collodion. No attention required. *Autopsy* fourteen days later found sutures in space as above mentioned, which held lower lobe of lung, diaphragm and liver against chest wall from seventh to ninth rib; ninth rib resected, which opened pleural cavity behind adhesion. Side of chest was cut away from second to seventh rib, showing pleura perfectly smooth, healthy, and lung inflated.

Only a trace of softening existed above sutures. No deposits of pus as in No. 5, either within or without thorax. The best case in all respects, both as to pneumonectomy and lung suture. No evidences of sepsis were found. Sutures were passed through skin. No special care during or after second operation was taken.

RESULTS NUMERICALLY STATED. Whole number of operations 27 on 20 rabbits. Operations were begun January 31, 1892, concluded April 16, 1892. Operations were as follows:

Pneumonectomies, 8. 4 on right side; 4 on left side. Average duration of life 32 days, 34 days, $31\frac{1}{4}$ days; longest time, 71 days; shortest, 18 hours. Both on right side. Lung removed entirely from lower lobes, upper portion, as root is opposite fourth space and there is less traction in respiration.

Attempted Pneumonectomy. Laceration of lung, chest packed with gauze. Four cases. Operations were done on left side. Average life, 21.07 days; longest 57; shortest, 7 hours.

Thoracotomies, 3. On account of bearing ether badly or other cause, operation stopped here. All on left side—No. 3, No. 7, No. 14. Average duration of life, $44\frac{2}{3}$ days; longest, 65; shortest, 21.

Suture of Lung to Chest Wall, 8. Three primary operations. Average life, $44\frac{2}{3}$; longest, 60; shortest, 23. 5 Secondary operations. Average life, 14.3-5; longest, 23; shortest, 10.

Pneumonotomy, 1. Third operation on No. 9, to see condition of lung following operation. Second on No. 9. Time until killed, 9 days.

Accidents, 3. *Pneumonectomies*. Too much ether (No. 2) 1.

Hemorrhage and Shock, 2. One hour each, No. 1 and No. 4; no packing or stimulants were used.

If the results are as good as this in rabbits, how much more can be expected in man, by intelligent co-operation?

Personal letters were received from W. W. Keen, Roswell Park, Senn and Fenger, stating they had not done pneumonectomies on man except for traumatic hernia, abscess, etc.

CONCLUSIONS.

Facts Learned by Operations above Described.

First.—Not to suture skin wound, except for purposes of pressure, as it heals too fast for deeper tissues, and retains discharges, and seems to provoke the formation of, or at last the retention of, cheesy matter.

Second.—To close external wound with interrupted stitches, as skin and muscles are so loose that they pucker and do not heal so rapidly.

Third.—To suture deep muscles, layer by layer, very carefully, so as to leave no spaces, to superficial muscles but not to skin.

Fourth.—To leave no more stump of lung than necessary, and the smallest pedicle which will be safe.

Fifth.—I think I have not been able to draw pleura and intercostal muscles close enough together—too little distance between ribs to leave enough tissue to get a stitch-hold which will bear drawing the parts together.

Sixth.—In first half of operations I allowed wounds to go too long without dressing, as skin healed too rapidly for deeper wound and retained discharges.

Seventh.—Without any constitutional evidences of sepsis—the greatest care and cleanliness being used—it seems that rabbits have a tendency to formation of a cheesy pus in healing of all wounds, operation or otherwise, as seen in bites in skin made by themselves.

This cheesy material was carefully examined several times for me by my colleagues in Los Angeles—Drs. Lasher and Lulu T. Ellis—who found it to consist of pus, broken-down granulation tissue, young cells, bacteria, but no tubercle bacilli.

It seemed at first that this material was formed by the pleura where chest cavity was opened (as in all earlier operations cavity was opened); but, later, it formed just as rapidly where thorax was not opened, and seemed to be a fatty degeneration of connective tissue.

The least of this cheesy pus was seen in wounds which were dressed every two or three days, thoroughly disinfected and freed from discharges, and in one case—unfortunately killed at night in pen by another male—none at all was seen.

There is certainly a greater tendency to this formation in deep wounds, rendered tortuous by large muscles of chest, which in operations are put in unnatural positions to reach middle of thorax, and the impossibility of restraining the movements of the animal, which create friction of muscles and tissues upon one another.

Different methods of suture have been employed, layer by layer, dressing often and packing wound to the bottom, at first firmly and then more loosely, with sterilized gauze, to compel healing from the bottom outward.

Another very important point learned by loss of several rabbits, before their time, was this, viz.: that no matter how weak or lifeless a rabbit leaves the table, either from the amount of anesthetic or shock, if stimulated, heart failure and death will be prevented, and it will live until the first dressing and perhaps for weeks. Then if it survives this ordeal (the fright of handling accentuates any other pathological condition) it will recover. A case in proof of this is No. 8, which lived apparently well one week after pneumonectomy of left lower lobe, and died immediately after first dressing. Autopsy showed pneumonia in left lung, extension of inflammation to heart, fibrinous pericarditis obliterating pericardial sac, which would have caused death, but the fright of dressing being added, death was immediate.

Pus formed about catgut sutures, within and without thorax, whether skin was opened or not. Silk was found to be a better suture material, as the time of operation for experiment is limited, but catgut was used always in suture of lung to chest wall, as it swells and closes puncture made by large curved Hagadorn needles used for this purpose.

Whether operations successfully performed on animals are justifiable in man, is a question for time and improved surgical methods to decide. I believe that operations proved by vivisection in laboratory to be possible and done successfully

upon animals (over whom, at most, you have but a limited control) to have stood a most severe test; that with the aid and assistance of human intelligence the subjects desiring to recover, and who can be made to restrain their movements. I believe that it will not be ten years until the operations detailed in this paper, now deemed curiosities of the laboratory, will be considered justifiable in man and done as successfully as ovariectomy by competent surgeons.

This is my first attempt at experimental work, and this paper represents three months of continuous study. I hope at another time to elaborate what little I have done and to be able to continue these studies, as they are very interesting to the investigator and in the line of progress.

If I have kept your attention too long, it is because of the difficulty of giving the results of such a number of experiments in a condensed form, so as not to lose their value.

I wish to thank Dr. Claire W. Murphy, of Los Angeles, my constant and enthusiastic assistant all through, for his valuable aid and help, and also to acknowledge my indebtedness to Drs. Lasher and Ellis, and Dr. Lorini of Coronado, and Mr. E. B. Alexander, for courtesies and assistance in these experiments.

CONDENSED SCHEDULE OF 27 OPERATIONS ON 20 RABBITS, BEGUN JANUARY 31, CONCLUDED APRIL 16, 1892.
PNEUMONECTOMIES.

RABBIT NO.	COLOR.	SEX.	WEIGHT.	DATE OF OPERATION.	SIDE.	LOBE.	INCISION.	DRESSING.	AMOUNT OF LUNG REMOVED.	ADHESIONS.	MANNER OF DEATH.	RESULT.	LITTERS.	REMARKS.
V	White	Female	5lbs	Feb. 4	Right	Lower	7th space	Sterilized gauze	Upper back; part of lower (½ lobe)	Firm	Pithed	Recovery	1	Healing delayed by too frequent dressings; oldest case and longest duration of life.
VI	Blue, Gray and White	Male	6½	Feb. 7	Left	"	5th space	"	Large portion of upper part of lower lobe	Firm	Killed in 2d operation	Recovery from 1st operation		Healing rapid.
XIII	White	Female	7	Feb. 18	Right	"	7th space	"	Large part of lower lobe	Firm to 7th and 8th spaces	Pithed	Recovery from 1st and 2d operation	1	Time of healing, 36 days. Diaphragm held high by adhesions.
XV	Brown	Female	5½	Feb. 7	Left	"	4th space	"	Upper part of lower lobe		Pithed	Recovery from 1st and 2d operation		Wound healed March 27; chest healthy. Diaphragm held high by adhesion.
XVII	Gray	Male	5½	Mar. 6	Right	"	3d space	"	Middle and greater part of lower lobe	Best result and best promise	Killed by No. 6; no other cause			Was doing finely until killed in fight.
XIX	Buff	Female	5½	Mar. 20	Left	"	7th space	"	Entire lower lobe	Firm	Pithed			Largest amount of lung removed (best case); rabbit in bad condition; whole lobe broke down, filled left cavity above 5th space; visceral pleura formed sac. Weight, 630 grs; normal weight of lungs is 150-180 grs.
VIII	Black and White	Female	5	Feb. 7	Left	"	5th space	"	Almost entire part of lower lobe	Lung adherent to chestwall	Shock and fright of dressing			Did well for one week. pneumonia and pericarditis.
XII	White	Female	5½	Feb. 18	Right	"	5th space	"	Nearly whole of lower lobe	Not time	Hemorrhage and Shock			Reaction slow; bled from part of intercostal wound; large clot in pleural cavity.

ATTEMPTED PNEUMONECTOMIES, WITH LACERATION OF LUNG; CHEST PACKED WITH GAUZE, ETC.

XI	Spotted Blue and White	Female	6lbs	Mar. 1	57	Le ft	Lower	4th space	Sterilized gauze	Lower lobe torn and packed with gauze	Firm	Pithed	Recovery	Gauze removed gradually, small amount remaining; entirely healed March 20; visceral and parietal pleura adherent, yet lung inflated and healthy.
XVI	Black	"	6	Mar. 3	4	"	"	Resected 4th rib	"	Lower lobe torn and packed with gauze; much shock; revived by stimulants	None, but some pleurisy	Died: pressure removed suddenly	Liv'd 4 dys; died 4 hrs. after packing removed	A wonderful result. Would have lived had gauze been left or removed gradually.
XVIII	Brown and White	"	6	Mar. 20	23	"	"	Section of 3d and 4th ribs	"	Lower lobe torn, packed, and gauze left	Gauze left	Pithed	Recovery	Gauze filling whole pleural cavity, agglutinated together and encroached on the other lung; only one lung for use.
III 2*	Brown	"	7	Feb. 7hrs.	"	"	"	5th space	"	Caught and tore lower lobe; packed and sutured	Sutured muscles	Shock	Death in 7 hours	Incision through old scar
IV	Blue, Gray	"	4 3-7	Feb. 4	1 hr.	Right	Upper part of lower	5th space	"	Upper part of lower lobe torn off by resp. traction; lung puffed when Space opened	None	Shock, very little Hem.	Death in 1 hour	Had not learned to pack and stimulate.

2* Second operation.

PRIMARY SUTURE, CURVED HAGADORN NEEDLES WITH CAT GUT.

IX	Gray	Male	6	Feb. 14	52	Right	Middle and Lower	Through skin and superficial muscles	Sterilized gauze	{ In 5th & out 5th; in 4th & out 4th; across from 4th to 6th. 3 Sutures.	Lung held firmly against chest	Pithed	Good	Slow healing: bitten by other male. (6)
X	Brown	Female	5½	Feb. 14	61	Left	"	Skin opened by incision	"	1 in 4th space	Lung never touched	Pithed; last killed	Good	No outside dressing; sealed collocation; healed in two weeks
XX	Gray	"	5	Mar. 20	25	"	Lower	Skin not opened	No dressing	1-7th to 5th 1-9th to 7th.	Diaphr'gm attached to wall; needle broke and stayed in wound	Pithed	Good	Recovery uninterrupted; rabbit never touched, except to examine; no outside dressing

SECONDARY SUTURE.

RABBIT NO.	COLOR	SEX	Weight	Date of Operation	LIFE	SIDE	LOBE	INCISION	DRESSING	INTERCOSTAL SPACES AND SUTURES	ADHE- SIONS	MANNER OF DEATH	RESULT	LITTER	REMARKS
IX 2	Gray	Male	6lbs	Mar. 13 April 5	23	Left	Upper	No incision	Sterilized gauze	In 4th and out 2d space	Upper lobe held against chest by firm adhesions	Pithed	Good		No pleurisy; no evidences of operation until intercistals reached; then suture holes seen filled with fatty substance
V 2	White	Female	5½	April 1	14	"	Lower	None; through skin and all	No dressing	1—in 8th and out 6th 1—in 10th and out 9th spaces	Adhesions, 8th space; diaphragm and liver pierced	Pithed	Good	1	No pus followed suture tract; sutures sealed with iodiform collodion; lung inflated above and below suture
XIII 2	White	"	7	April 1	14	"	"	None; through all tissues	No	1—in 7th and out 6th 1—in 8th and out 6th 1—in 8th and out 9th spaces	Firm adhesions of lower lobe to chest wall	Pithed	Good	1	Pus surrounding suture within and without thorax; sac in liver, otherwise liver and lung tissues normal; lung fully inflated by blow-pipe
XV 2	Brown	"	6	April 1	10	Right	"	None	Sterilized gauze	In 6th and out 7th space	Firm adhesions of lower lobe to chest wall	Pithed	Good	1	Organs normal; pregnant (9), nearly full term; in skinning tore out suture, which was only softened
VII 2	Black	"	5	April 1	10	Right	"	None	No Dressing	In 7th and out 6th space	Suture did not enter lung	Pithed		1	Suture entirely covered by lymph; no pleurisy; lungs normal and fully inflated

THORACOTOMIES.

III 1	Brown	Female	7	Jan. 31	21	Right		4th space	Aseptic dressing	Lung not touched	Right chest normal; a mere line seen in pleura	Died after 2nd operation shock	Recovered from operation	1 Feb 7	Lung collapsed when chest opened, so operation stopped, rather than let it die on table
VII	Black	"	5	Feb. 5	65	Right		4th space	"	Closed by suture and included 1 rib in suture	No sign of pleurisy	Pithed	Recovery rapid; reaction good	1	
XIV 1	Black	"	5½	Feb. 21	48	Left		4th rib resected, ¾ inch removed	"	Entirely healed March 20	Pleural effusion, much cheesy matter	Pithed	Recovery slow		First rabbit to have pleural effusion

ACCIDENTS.

I	White	Female	6½	Jan. 31	Right	Lower	9th space		Lung collapsed and torn; died on table		Pithed to end suffering	Died.	Some bleeding; incision too near diaphragm.
II	"	"	6	Jan. 31	Right	Lower	6th space				Too much ether.	Died.	Death before lung caught.

PNEUMONOTOMY.

IX ₃	Gray.	Male.	6	Mar. 27	Right.	Middle and lower.	Incision through old scar in 5th space.	Bichloride gauze dressing.		Right chest inside showed only plastic material about wound, closing off lung; re- moved from pleural cavity.	Pithed.	Good.	Adhesions firmly attached to 4th and 5th spaces, cut into 6th space and was into pleura behind adhesion; closed by suture.
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Figures after roman numbers indicate different operations.



